Chiral Ordered Phases in Frustrated Quantum Spin Chains

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We study the ground-state properties of a one-dimensional anisotropic spin system with the antiferromagnetic nearest-neighbor coupling J_1 and the frustrating next-nearest-neighbor coupling J_2. The model Hamiltonian has the form,

$$\mathcal{H} = \sum_{\rho=1}^{2} \left\{ J_\rho \sum_l \left(S_l^x S_{l+\rho}^x + S_l^y S_{l+\rho}^y + \Delta S_l^z S_{l+\rho}^z \right) \right\}, \tag{1}$$

where $\vec{S}_l$ is a spin-S spin operator at site l. We concentrate on the case of XY-like anisotropy $0 \le \Delta < 1$. We are particularly interested in the possible gapless and gapped "chiral" phase, in which the z-component of the vector chirality $\kappa_l = S_l^x S_{l+1}^y - S_l^y S_{l+1}^x$ exhibits a finite long-range order while the spin correlation decays either algebraically or exponentially. In the chiral phases, only the parity symmetry is broken spontaneously whereas the time-reversal and translational symmetries are preserved. It has been suggested by the bosonization approach with a mean-field approximation[1,2] that in the XY case ($\Delta = 0$) the system for general S exhibits the gapless chiral phase for large $j \equiv J_2/J_1$.

In the presentation, we report the results of our study[3,4,5] in which the ground-state phase diagrams of model (1) are determined numerically for $S = 1/2, 1, 3/2, 2$ using the density-matrix renormalization group method. The main results are summarized as follows.

- The gapless chiral phase appears in a broad region of the phase diagram for general S. By contrast, the gapped chiral phase is found for integer S in a narrow region between the Haldane and gapless chiral phases, while it has not been identified for half-odd integer S within our numerical accuracy.
- As S increases toward the classical limit $S \to \infty$, the region of the gapless chiral phase converges smoothly toward that of the classical helical phase, $j > 1/4$ for $0 \le \Delta < 1$.

We also present the ground-state phase diagram of the frustrated $S = 1$ Heisenberg chain with uniaxial single-ion-type anisotropy.

[1] A. A. Nersesyan *et al.*, Phys. Rev. Lett. **81**, 910 (1998).
[2] P. Lecheminant *et al.*, cond-mat/0007138.
[3] M. Kaburagi *et al.*, J. Phys. Soc. Jpn. **68**, 3185 (1999).
[4] T. Hikihara *et al.*, J. Phys. Soc. Jpn. **69**, 259 (2000).
[5] T. Hikihara *et al.*, cond-mat/0010283, to appear in Phys. Rev. B.